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ABOUT THIS ISSUE

On November 5, the Esso Research and Engineering Company dedicated a Reseach Center at Florham Park, New Jersey. The principal speaker on that occasion was George B. Kistiakowsky, whose address is reproduced as our first article. Presently the Special Assistant for Science and Technology to the President of the United States and an eminent scientist, Dr. Kistiakowsky makes a splendid presentation of the necessity for industry to give support to basic research not only in its own laboratories, but also at universities and other institutions.

At this stage in the development of our civilization, we feel justified in saying that the mechanics of communication have reached superb levels of development. Can the same be said for the interpretation of communications? By no means. Our second article presents an analysis of certain areas which, though at the very heart of the communication process, have not received the attention deserved. The author is Carl Pacifico, who has delved into the abstruse field of human communication and, in fact, has published a book, *Exploring Life's Secrets,* on that general subject. He is Vice President and General Manager of American Alcolac Corporation of Baltimore, Maryland.

A thoughtful analysis of the functions of a middle-echelon manager is presented in our third article. The author examines his duties toward the men and correlates that phase of the job with his responsibilities to the company. It is clear that successful efforts in both aspects lead to a research section dominated by high morale and achievement. He tells of his own specific field of work, but the observations have wider application. Dr.

O'Shaughnessy is a section leader in the Development Department, Research and Development Division, American Viscose Corporation.

With this issue, we commence a series of Proceedings on the IRI Study Group Conferences. Dr. Thomas H. Vaughn presents a brief and lively account of the origin and reasons for the conferences. He speaks with authority for, as president of the Institute, it was he who appointed and guided the committees that demonstrated the need, the feasibility, and worked out the techniques for these intimate sessions. Dr. James A. Bralley, who devoted much time and effort to the six conferences of 1959, reports upon the proceedings of the two which had as their topic The Environment for Creativity. His report, the first part of which is presented in this issue, is interesting reading for all echelons of scientists and research managers. Dr. Bralley is Director of Chemical Research of A. E. Staley Manufacturing Company, Decatur, Illinois.

BASIC RESEARCH: AN INDUSTRIAL RESPONSIBILITY*

GEORGE B. KISTIAKOWSKY

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It is a happy occassion for me to participate in so felicitous an event as the dedication of a new research center. To those of us accustomed to the austere atmosphere of university laboratories, facilities provided by industrial organizations seem magnificent indeed. It is typical of the forward-looking spirit of American enterprise that the Esso Research Corporation should crown its already excellent facilities with this splendid new center.

Possibly by intent, the inauguration of this center coincides with the centennial of the petroleum industry. It has been a century of dramatic progress in which the increase in production of crude oil—from 2,000 barrels in 1859 to $2^1/_2$ billion barrels currently—is only a vague yardstick. A much more realistic measure of the impact of the oil industry upon industrial growth is to be found in the increase of our use of mechanical energy. This has multiplied 185 times in ten decades. Machines now do 99% of the work in this country, while in the 1850's only about 35% of all work in the United States was accomplished by machine. The rest was done by men, women, children, and draft animals. The effects of the petroleum industry on the growth of the automotive

* Remarks delivered at the dedication of the Esso Research Center, Florham Park, New Jersey, November 5, 1959.

and aviation industries are infinite and, of course, too obvious to mention.

In the last 25 years, petroleum has taken on new significance as a source of synthetic organic chemicals. Important industries have grown up around the production of detergents, synthetic rubber, synthetic fibers, and plastics. Out of these flows an unending stream of products of bewildering variety. In our households today is a host of colorful and useful items which would have been quite unfamiliar not only to our grandparents, but to our parents as well.

The growth of the petroleum and petrochemical industries is typical of American enterprise and initiative. The growth of the industries owes a great deal to bold risks, effective management, and the application of modern industrial techniques; they also owe much to research. I refer not only to the large-scale technology fostered today by most major industries, but more specifically to the basic work of such men as Sabatier, Staudinger, Whitmore, Hinshelwood, and a host of others.

Several years ago, one of your distinguished executives was quoted as saying of your company's research and development activities: "We're really just another operating department, except our job is to turn out a product called technology. The product is worth no more than it can be bought for on the open market." I would not disagree with this statement, provided it means what it must mean to other departments of Standard of New Jersey. I trust that it would be understood in the spirit of the courageous world-wide gambles of your parent company; of the long-lasting and comprehensive geological explorations in the wildest and most inaccessible parts of the world; of huge investments in drilling wells, many of which necessarily turn out to be dry. For a reason that a simple scientist cannot fathom, your parent company chooses this path rather than waiting for others to do all the exploratory work and then buying the product as it flows from other peoples' wells. What, then, is the equivalent approach of an "operating department" turning out technology?

Such an approach lies in the careful assembly of a bold research staff whose active minds pioneer the frontiers of science in the same spirit that your geophysicists and geochemists search for new wells. It is the eager and exploring minds that will convert these magnificent structures from brick and mortar that they are into the living entity selling technology to your parent company at less than market price and, in the process, I must emphasize, contributing to American scientific leadership. In this respect, also, you resemble an operating department, which consists not of ships or drilling rigs or refinery equipment, but of men who have been given the right tools and the kind of leadership that results in a job magnificently done.

I am not an expert in the oil business, but I do know that profits do not lie in geophysical explorations and oil-well drillings in new locations—they are made when wells can be added where flowing wells have already produced the pools of black gold and through the expert management of established resources. And yet your parent company continues to push ahead into new and hitherto unexplored locations. For research and development the analogy lies in the fact that, although immediate profits result from process development, from clever engineering, and from product improvement and controls, the enlightened management insures also that you may explore the unknown by basic research to insure long-range progress.

Of course, if you wish to see me hoisted on my own petard, you might inquire why it would not be better for an industrial company to wait until somebody else turns up new discoveries and then pick up what looks good industrially and concentrate on the rapid conversion to profitable processes. Occasionally, no doubt, this is just the right procedure, and many companies have undoubtedly profited by following it. But consider what would happen if all industries adopted this attitude as the standard operating procedure. Not only would the national effort in basic research be seriously diminished, but industries would lose competence to select the right products of basic research for develop-

ment. I submit that industry has no choice better than to continue a vigorous basic research program, if you want to be sure at all times that you will be truly first; that in key technological areas you will be the undisputed leader instead of being part of the crowd that fights for the left-overs.

Such a program would include not only the pursuit of research in your own laboratories but support and encouragement of research that is carried on in the colleges and universities. There are disinterested and altruistic reasons for supporting university research; more important, there are also very practical ones. It is impossible to predict in advance which of the leads that basic research uncovers may have significant economic potentialities. One might not suppose, for example, that the botanical studies of the toxicity of a common western plant known as locoweed would result in a significant tool for mineral prospecting. Nevertheless, studies made by a Columbia University botanist led to the discovery that the toxicity of this plant is attributable to its large uptake of selenium. Selenium is found near uranium, and now geobotanists can furnish important leads to the discovery of this and other important metals, for research has indicated that there are clear relationships between certain types of vegetation and their chemical environments.

Geobotany and the still more recent field of polynology, the study of fossil pollens, are extensions of the work in geochemistry, which industry has been applying successfully to the problem of prospecting. The present applications of these sciences would not have been possible, however, except for the very basic work done earlier and being continued at the present time.

The work of Dr. Joseph A. Cushman is now well-known to the oil industry, but it is unlikely that, had the industry been calculatingly seeking a promising scientist to support, it would have selected a micropaleontologist engaged in the study of fossilized shells of the single-celled marine animals known as *Foraminifera.* Dr. Cushman, of course, did not undertake his studies of these small creatures with any view to the possible economic importance

of his work, but now these minute fossils are used in industry in identification of rock strata; this has applications in determining sites of water wells and, on a much wider scale, in the location of oil-bearing strata.

Much of the petroleum industry depends nowadays on the use of catalysts, and yet one does not need to search far back in history to discover when basic research into the nature of heterogenous catalysis by such men as Sabatier, Ipatieff, Taylor, and Natta stimulated industrial applications.

What would the petroleum industry do now if it did not have such research, analytical, and process control tools as the mass spectrometers and NMR and IR instruments? Even the first of these was born less than 50 years ago, from the experiments of J. J. Thompson on the trajectories of gaseous ions in electric and magnetic fields. The nuclear magnetic resonance and infrared instruments are much younger still, but neither Purcell and Bloch, when they demonstrated nuclear magnetic resonance, nor the many people working on infrared spectra, were motivated by the potential industrial applications of their discoveries.

Where would our society be without synthetic polymers, and what fraction of the petrochemical industry would be in existence? Yet, one need not search long to discover the origins of all synthetic polymers in basic research laboratories of Staudinger, Carothers, Ziegler, and so many others.

These examples and others like them lead to an important generalization. We are experiencing a new revolution, rather than merely an accelerated phase of the old Industrial Revolution. C. P. Snow, in his Rede Lecture at Cambridge, draws a clear distinction between the two. He characterizes the Industrial Revolution as the gradual introduction of machines, the rising employment of men and women in factories, the shift in population from agriculture to manufacture and distribution which began in the eigteenth century and extended to the early twentieth:

"Out of it grew another change, closely related to the first but far more deeply scientific, far quicker, and probably far more prodigious in its result

—the application of real science to industry, no longer hit-and-miss, no longer the ideas of odd 'inventors.' "

He observes that dating the second change is largely a matter of taste and he himself places it at the time when atomic particles were first used industrially. He declares:

"I believe, the industrial society of electronics, atomic energy, automation, is in cardinal respects different in kind from any that has gone before, and will change the world much more. It is this transformation that, in my view, is entitled to the name of 'scientific revolution.' "

"This is the material basis of our lives; or more exactly, the social plasma of which we are a part, and we know almost nothing about it."

Two points might be made here. The first is that we need to take active steps to see that people do develop knowledge and understanding of this "social plasma" of which we are a part, and the second is that our national research and development effort should nourish and enrich it.

Experiences in the position which I am privileged to hold make me very much aware of these problems and also place emphasis on certain aspects of them. I refer to our competition with the Soviet Union which covers a broad front, from our efforts to obtain the most effective modern weapons to insure our ability to deter and, if necessary, to resist aggression, to our efforts in maintaining intellectual, scientific, and technologic superiority and so insuring the willing acceptance of our leadership by the free world. The deadly earnestness of this competition should make all of us concerned about every technological area in which the Russians are conspicuously advanced; for instance, geochemistry and oceanography—indeed the entire field of geophysics—or the development of very large rocket boosters needed for the more spectacular aspects of outer space exploration. Whenever progress by others in such areas has an impact on our security, we, as a nation, have no safe alternative but to make a determined effort to overcome the lead. However, as a scientist who has had some experience in both basic and applied research, I believe that, except in areas critical for our national security, it is both illogical

and unsound for us to chart our own technological course on the basis of what the Russians are doing. In terms of the total technology, the two nations are at quite different levels of development and hence the requirements for applied research, engineering, and other aspects of technology are correspondingly different. As far as basic research is concerned, its full support and encouragement are important to any nation that would hold its own in the scientific revolution that characterizes our age. To the leader of the free world, such support is urgent and indispensable.

American industry has here a dual responsibility: the development of a basic research program that sustains the industry and insures its growth as well as the sharing in the enlightened support of a broader body of scholarly research outside industry, which is equally indispensable for industrial progress.

My observations on basic research in industrial laboratories suggest that it is sort of a tender flower, apt to wither on the stem, unless management takes good care to nourish it. The type of organization that is appropriate for development and engineering seems to malfunction when applied to basic research. Let's look again at an operating department. I have no doubt that precise procedures can be developed for the operation of a well-established venture, say, a refinery that is just like several others already on stream; but can standard operating procedure be written for the oil exploration team that is venturing into the middle of the Sahara Desert? Should not a great deal of initiative be left to the leader? The situation with respect to basic research is similar. You have to find the right men; you have to give them the right tools; you have to tell them generally where to head; but you must let them use their own judgment thereafter, and you must not give up if the first wells turn out to be dry.

I seem to have again tried to draw analogies between a research and development organization and an operating department. This is fun, but it cannot be carried through completely. A research organization differs from an operating department at least in one very major detail, and that is the extent to which an

R&D establishment is dependent upon outside inspiration and creative efforts. You have to engage in basic research because otherwise you are certain to become second-rate, but you cannot isolate yourself from the mainstream of science and you must make full use of it, regardless of its source. Moreover, since your own success depends upon a steady influx of first-rate young scientists with the proper kind of training, it is to your advantage to insure this influx. The only way I know of accomplishing this is to support scientific education and research as an essential part of your own mission.

COMMUNICATIONS—THE BRIDGE ACROSS THE CHASM

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One of the characteristics that distinguishes human beings from the lower animals is our much greater range of communications. This ability to communicate has been a major factor in progress. Certainly our civilization could not exist without means for the efficient transfer of information.

The problem is no less important to the individual. We have a high regard for the man who can communicate and have our doubts about the intelligence of the one who cannot. A large amount of research has been done in the broad field of communications, and much money has gone into the development of its technology, but this work has almost exclusively considered the physical transfer of signals, which are nothing more than the carriers of the communication. Very little has been done with the fundamental unit of the communication system—the human brain itself.

As a simple illustration of some of the problems involved, consider a group of men, obviously working together, each playing with some little balls. Every now and then, one of the men stops and throws a ball at one of his associates. He doesn't concern himself whether the ball is caught or not, but continues his work. Peculiar? Yes, but wouldn't the action be familiar if the word "idea" were substituted for "ball?"

This analogy is simple enough to show clearly that there is no communication by the single action of transmitting; there must be reception. Transmission alone permits but does not assure communication.

This fundamental point can be expanded by drawing a somewhat more complex analogy. This time, consider a man with a receiver-transmitter who wants to communicate with someone with a similar set a few miles away in the mountains. He can send a message, but this alone does not ensure that it will be received. The receiver may not be on; it may be tuned to another channel; atmospheric conditions may not permit the message to get through. There is no need to linger on this point. The similarity to human communication is obvious. The point here is that communication cannot be assumed to have taken place until a signal is returned showing that a message was received. Perhaps a prearranged flare will assure the sender that his associate received a message.

Has there been communication? Perhaps, but perhaps not, for what assurance is there that the message received is the one that was sent? Again, there is no need to press this point, for it is obvious that, for any complex message sent, the only assurance of reception is a retransmittal of all pertinent information received (though this reply need not be by the original technique). That is, if a message is sent by Morse-code telegraphy, the sender could be satisfied that it was properly received if he saw a copy of the translation. The method of communication may have been changed from electrical impulses to marks on paper, but the sender has received a retransmittal and can compare it with the original. The point is simple but most important. Complete communication can never be assumed unless there is adequate back-transmittal to check against the original.

This technique is certainly adequate to check on the physical transmission of information, but it immediately runs into a serious practical obstacle. In our society, such a check on reception is considered downright impolite. An adult sending a child on an

errand can ask him, "What did I say?" but only the bravest supervisor would use this approach on his assistants, and very few workers would try it on the boss. To avoid leaving the mainstream of the discussion, this problem will be left where it is temporarily while we return to the analogy.

Assuming now that the message reaches the recipient exactly as intended, it must still pass over another transmission network—that from the receiver's sensory organs to that portion of the brain where it is comprehended. And this is by far the most difficult part of the problem of communication.

The signals received by the senses must pass over the nerve system that connects with the comprehension area where the electrochemical signals are converted to "thoughts." It must be remembered that the signal received by the senses is just a signal, and nothing more. This is important. If the signal is received by the ears, it is nothing more than a certain rate of vibration of the air; if it is received by the eyes, it is only a pattern of electromagnetic radiation identified as a specific combination of form and color. Every interpretation of these basic data is contributed by the association areas of the receiver's brain. What assurance is there that the receiver's brain will interpret each signal in the same way as the sender's brain?

It is easily shown that all brains do not give each signal the same interpretation. For gross differences, we need only consider different languages. The same sound or the same symbol, may have very different meanings in different languages. While no one would make the mistake of trying to communicate with a person in a *language* not understood by him, few people are equally careful that their listeners understand *individual words, phrases,* or *concepts.*

There is a most important point here. The significance of a signal is entirely that given it by the receiver. It may be the same significance intended by the sender, or it may be something entirely different. The significance will depend on which brain pathways the signal takes. Thus exactly the same signal can have

different significances, even to the same person at different times. As this may seem puzzling, note that there are many words that have different meanings. We distinguish among them by the context in which they are used.

A second example is more subtle. The receiver selects a meaning for a signal depending on his mood, his recent activities, or his traumatic experiences. These factors are all related in that they indicate the brain pathways currently being used and thus the pathways that a new signal will use. The following experiment may provide a suitable illustration. Read only one of the three following paragraphs. Do not read the others.

(*1*) Baseball is an exciting game because of the conflict between pitcher and batter. It is a great thrill to see a pitcher throw a ball and an equally determined man swing a stick at it and miss.

(*2*) The capitalists have all the advantages. We must organize and use every weapon to force them to give us what we want.

(*3*) Bowling is a fine recreation for the whole family. It's a lot of fun to see a ball scatter all those pins.

Now, what is the first meaning that comes to your mind at the signal "strike?" Although this signal has many meanings, the chances are that your first association was that of the paragraph you just read, even though the word "strike" did not appear there.

Reflection discloses some of the enormous obstacles to communication associated with this point. Almost all people will agree on the meaning of some signals like "sun" and "water," but there is little chance that all will associate exactly the same meanings with words like "God," "love," or "courage." Also, different subgroups, even in the same culture, may attach different meanings to the same signal. The signal "research" means very different things to the vice president of research and the vice president of sales in almost all companies.

Equally important, no word stands alone, but instead has a large number of associations inextricably attached to it from previous experience. That is, the signal triggers all sorts of related concepts in addition to the one intended. For example, the word

"courage" may also call to mind war, business, and many other thoughts; moreover the associations will be different with each individual. Some of the problems this creates will be explored later in the discussion of "complex messages."

The problems are not yet all identified. There is still another obstacle, one that requires a little visualization. A wooden object with four legs and a flat top can be referred to as a table. In our language we would have no disagreement on the selection of this signal to represent the object. But consider the reverse. If the signal "table" is used, which of the many kinds of tables is to be visualized? A marble coffee table? A round dining table? Is this the kind of table that the sender intended? Please note that this point is not one of precise definition. Rather it is inherent in the use of a single signal for a number of related but somewhat different objects.

All of the difficulties discussed so far apply to the simplest communications. An additional major difficulty arises with complex messages. Different pathways are stimulated by different parts of the message. Since the individual stimulations are almost simultaneous, no all-called for motor actions can take place. Usually, perhaps always, only the most important will occur, but it must be noted that this action will be that one which is most important to the receiver, not to the sender.

An example will illustrate this point. A supervisor is dissatisfied with the research results of his assistant. He can express his dissatisfaction in various ways, but perhaps he uses the signals, "Even a fool would have known that temperature was too high." No doubt his intention is that of communicating information concerning temperature relations, but the assistant will also receive signals concerning his own competence and status in the eyes of his boss. These signals touch on his primary needs; those concerning temperature do not. The former are then the signals to which he will react. The example taken is a gross one, but probably every complex message contains signals of varying importance to the recipient.

One aspect of complex messages that is seldom recognized is that of unintended communications. All of us are continually communicating with each other. We send out signals by the way we walk, by the clothes we wear, by our manner of speaking, indeed, by every waking action. Even omitting those signals that we call writing, it is quite likely that the major part of all communication is through the sense of sight. For example, if we see a man with a raised knife creeping toward us, we don't need any aural signals to communicate his intentions.

Of course the communication need not be so violent. It may be so subtle that the point is missed by some receivers. In general, however, we get the message. We know if the other man is afraid, feels superior, or is defiant. We may claim occasionally that our associates don't understand us, but more likely the problem is that they understand us too well.

At this point it will be helpful to sum up the background information.

(*1*) The signals used in communicating have no significance in themselves. Significance is attached entirely by the receiver, and this may or may not be the same significance intended by the sender.

(*2*) The significance attached to the signals by the receiver will depend on his previous experience, his present problems, and his recent activities, in short, on his current brain pathways.

(*3*) Communication occurs through all the senses and includes both intended and unintended signals.

(*4*) A signal cannot include all the associations intended by the sender.

(*5*) The responsibility for communication remains with the sender until he is certain that the message has been properly understood by the receiver.

Examining the mechanism of human communication in this way, we cease to be astonished at how poor our communication is and begin to wonder that we can understand each other at all. Still, this approach does provide a basis for improving the transfer

of information. The principles are simple, even though our bad habits make the application difficult.

(*1*) Prepare the recipient's mind by providing all the basic brain pathways required to understand the thought to be conveyed. A roof cannot be put on a house before the foundation and supporting walls are constructed.

(*2*) Use concrete words as much as possible. Where possible, factor abstract words into concrete components. For example, "tailings" from a still is an abstract word, for we cannot touch or see tailings. We might substitute "material boiling above 135°C."

(*3*) Where abstract words must be used, define them carefully. This is also true for any new terms introduced.

(*4*) Avoid in technical communications words that have strong emotional connotations.

(*5*) Try to present the message at a time when the recipient's mind is ready for it—not when he is concerned with other matters of greater importance to him.

(*6*) Keep the message as concise as possible to avoid introducing extraneous signals.

(*7*) Eliminate, by explanation, erroneous interpretations that could be made of the information to be sent. This requires projection to the mind of the receiver to try to predict how he will interpret the message.

(*8*) Limit the total amount of information to be conveyed at any given time.

(*9*) Try to get the message to the receiver through as many different senses and in as many different forms as necessary. This is very much more effective than mere repetition.

(*10*) At times it may be useful to attach the message as a "rider" on some unrelated message that is sure to reach the receiver's comprehension. By far the most effective communications are those concerned with some need of the recipient.

(*11*) Remember that there is always more conveyed than the basic message itself. If the message is a technical report, the cover, the quality of the paper, the number of misspellings all convey

messages which usually, though not always, will influence the recipient through association with the message itself. Similarly, in personal communications, the appearance of the individual, his smile or frown, is also conveyed.

(*12*) Check back. Simple repetition indicates only that the physical message is received and does not assure correct interpretation. Proper checking on the objectives intended is important. For example, if the sales department requests a certain product from research, the research group can prepare a memorandum outlining its understanding of the properties of the product, its cost, and so on. If the sales department accepts the memo as accurately indicating its desires, communication has probably been accomplished. (Note that this could not be assumed if the sales department had merely outlined its desires in a memo as there would be no assurance that the research department would interpret it as it was intended.)

(*13*) Remember that, in addition to the usual obstacles, there is a special problem in communicating on different levels in a company. The problems are seen differently. No new principles are involved but extra care must be taken to avoid misunderstanding.

Obviously it is very difficult to communicate well or more people would be able to do it. We look upon those few people who have learned the principles with some awe. Unfortunately the number has been few because the learning of good communication principles has been intuitive, polished by experience. Nevertheless, while the practice of poor communication methods is conditioned almost from birth, there is no fundamental reason why good communication principles cannot be taught and major improvements obtained. Alert managers should be able to establish rules for higher standards of performance in communications just as higher standards of safety have been established. The application of these principles will not be easy, but surely the results are worth the effort.

MIDDLE MANAGEMENT OF RESEARCH AND DEVELOPMENT

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Introduction

In a large company, top R&D management is typically concerned with broad and general objectives, middle management being concerned with direct guidance of research in an organizational unit of limited scope and purpose. The middle manager faces the basic problems of organized research and development at first hand.

The synthetic fiber industry is hardly typical of process industries in general; its chemical base is limited, and the principal operation, the spinning of fibers from polymer solutions or melts, presents problems in physical chemistry, physics, and equipment engineering. Research and development in direct support of manufacturing operations in the fiber industry tend to be more intensive than extensive and more physical and mechanical than chemical. The technical problems of a manager in charge of a section which supports an existing group of fiber products are, to a degree, special to this industry. Exploratory research aimed at long-range diversification, basic research on the scientific back-

ground of another industry, or work in support of chemical operations for a wide range of products would present very different problems. On the other hand, middle-echelon management may be presumed to have much in common throughout the range of research and development activities.

This paper presents an analysis of its functions, formulated in the context of our specific operations but generalized in the hope that it will have a wider range of applicability. The principal categories of problems of the middle manager—those which relate to the planning and direction of a technical program, and those which relate specifically to his individual relationships with creative technical personnel—are discussed separately.

The Middle Manager's Directive Function

The functions of the middle manager in establishing and directing a research program are described as a sequence of operations in time, for ease of exposition. Actually it is only in the exceptional case of a complete reorientation of program that events would occur in such a temporal sequence; ordinarily they overlap in time and go on more or less continuously.

Research is done to develop new products, to improve existing products, to support other research, to reduce costs, and in general to add to the versatility and flexibility of a manufacturing enterprise in offensive and defensive competition. In an organization consisting of a number of specialized units, the manager's first task is to understand fully the purposes of his unit. If the unit supports manufacturing operations, the problem becomes the understanding of the branch of the industry concerned in its technological and business aspects, especially in relation to direct and indirect competition. From this understanding he proceeds to formulate objectives for research and development, and then to select from among them the small number which a limited staff can undertake with sufficient intensity and continuity of work to offer hope of success.

In the selection of problems for attack he should consider (*1*) the short-range economic value of a solution; (*2*) the possibility that a successful solution will open the way to other developments of economic value, i.e., its longer-range potential; (*3*) the state of technical knowledge in his unit and company and the value of a problem to progress in "background" knowledge; (*4*) the suitability of personnel, present or obtainable, for an attack upon the problem in question; and (*5*) the comparative merits of different sets of choices from the standpoint of mutual reinforcement of the work on problems related in one way or another. Some objectives may be of such self-evident importance that the problem and the necessity of its solution are perceived almost simultaneously, while other choices may be difficult. In any individual case, selection is an exercise of judgment after gathering of information and analysis.

Once the objectives have been selected, it is important that these objectives, the reasons behind them, the individual assignments, and other pertinent matters be discussed in sufficient detail with the professional staff who will conduct the work. Each professional should know fully his own responsibilities and the relationship of his work to the program as a whole, especially to any other work with which his must be coordinated.

When begining a new assignment in an unfamiliar field a professional should not be subjected to pressure, but as the work proceeds, in a product-supporting unit, some pressure becomes necessary. This pressure can be made self-applied, to a degree, by stipulating (*1*) that the work proceed according to plans, (*2*) that senior professionals develop and propose their own plans (subject to review with the manager), and (*3*) that progress be reviewed at stated intervals and further plans then considered and adopted. This implies that the manager will not tamper directly with the execution of a plan once he has approved it; if change is needed he will discuss the need with the man responsible for the plan.

The matters above are all occasions for formal communication between manager and professional man. It is important that

there grow up easy informal communication as well. It is particularly desirable that frequent technical discussions take place—they are indicators of and stimulators of interest and ideas—and that the manager participate on an informal basis, with managerial authority left aside. The communication of ideas, as distinguished from assignments, takes place most effectively in easy informal discussion. The manager will know his men, the real problems and status of the work, and the technical side of his own job the better for such discussions.

The work in hand will involve *research*—the search for knowledge—and *development*—the effort to create new technology. Development may be the overriding aim, but it derives its basis from research, often needs the support of parallel research, and has its own research aspect which cannot be neglected or delegated to others without its lapsing into blind empiricism. Sharp distinction between research and development does not appear to be as useful as emphasis, in both, upon an analytical approach, adequate use of the literature (the cheapest and often the most effective form of research), critical evaluation of data, and the search for underlying causative mechanisms.

The cellulosic fiber industries are old, and most possibilities have been tried; the probability of success in new attempts is increased by application of modern scientific knowledge, apparatus, and instrumentation. The development engineer needs to give thought to what the molecules are doing, and the research scientist to recognize that the phenomenological study of a spinning process may be as challenging and as difficult as the synthesis or fractionation of a polymer. It is most important that supportive work such as we do be conducted by a balanced staff containing both scientists and engineers and that the two groups learn to speak the same language and to cooperate effectively.

The middle manager has other duties. To his superiors he owes effective work on the part of his unit, cooperation in application of policies, and adequate upward communication, both formal and informal. He must maintain active liaison with the manu-

facturing, sales, and company management men involved with the operations his unit supports. This is essential to his role, both as a source of information and as a channel by which research can contribute to company thinking and eventually to technology.

The criterion by which a research and development unit, a manager, or a professional scientist or engineer should be judged is effectiveness in achieving objectives over a period of time. Achievement is an aggregate of day-to-day activities. The day-to-day activities themselves may be judged on various more or less valid bases but there is danger that, in focusing judgment on the parts, the overriding importance of the whole may be obscured and that the degree to which the whole is more (or, in some cases, less) than the sum of its recognizable parts will be overlooked. In particular, effectiveness should be emphasized rather than day-to-day efficiency. Research is intrinsically inefficient as compared with repetitive productive operations. The only kind of efficiency worth striving for is that which follows naturally from the effort to achieve objectives as quickly and directly as their nature permits, and any directive pressure needed should be applied toward this end.

Relationships to Individual Employees

So far we have considered the technical and business objectives of the unit and the direction of the staff as a group in relation to the objectives. While success in these matters does much to allay individual problems, his individual relationships with members of his staff constitute an important and partially separate aspect of the middle manager's functions. The key idea is that professional scientists or engineers working in research and development are or should be creative. Creative work calls for a degree of intellectual autonomy, concentration, and emotional involvement in the achievement of purposes beyond anything necessary in work that is routine or repetitive. In order that the professional scientist or engineer devote himself to the work with

the completeness required, it is necessary that he be relatively free of conflicts and discontents connected with his work situation. His job should be a satisfactory economic base for the present and for the future, an opportunity to achieve professional self-development, and a basis for the feeling that his life is being devoted to something worthwhile. He should have confidence in and respect for his employer, hope for his own future, self-respect, and satisfying day-to-day experience.

If the employee's basic purposes and the purposes of the employer fuse to the extent that these elements are realized, the employee experiences a contentment, loyalty, and emotional involvement in his work that may be called identification with the employer. This is the principal basis of employee morale; excessive turnover reflects wholesale failure of this process.

The employee identifies with his company and his unit, but the images of company and unit are largely fusions of his impressions of individuals. The middle manager, as primary representative of the company and head of the unit, is a key figure. Since interpersonal relations are, to a degree, the bases of identification, some irrational emotional factors are necessarily involved, and the process cannot be entirely predictable or manageable. In the absence of individual negative factors, the middle manager who inspires respect by competence in his own functions and who is friendly, interested, and helpful toward his staff will build a high type of morale. If the same qualities are perceived in other individuals in key positions the process will be reinforced.

It is helpful for the middle manager to be aware of the role that the professional's job should fulfill. He should seek to make assignments that will mesh as well as possible with the deeper interests of his staff members and to guide them in seeing connections between their desires to progress as scientists and the technological problems with which they must be concerned. It is helpful for the manager to be aware of certain qualities in staff members—personal ambition in excess of abilities, resistance to authority, cynicism, excessive passivity, are among them—which

can impede or prevent identification and in some cases act destructively upon the morale of others. He should also be aware of qualities in himself which may sabotage morale. Any of the qualities mentioned above can do so, as can the indiscriminate setting of too high standards for performance, any kind of unfairness, egotism, vacillation as to purposes or other evidences of ineffectuality. Most negative qualities in the manager will be minimized automatically if he makes a serious effort to develop a friendly, positive, and accepting attitude toward each professional as he is, and attempts to guide him and inspire him to self-development and more effective performance in a way that encourages him to recognize and build his strengths and does not put his weaknesses in focus unnecessarily. We must not forget that we cannot buy creativity nor demand it, chiefly because some of the essential conditions for creativity cannot be supplied by the individual at will.

What has been said of relationships to professionals holds, though less directly for the manager, for nonprofessional technicians, as their interest, enthusiasm, and intelligent performance are important to progress. The friendly personal interest and guidance which the manager owes the professional may well be applied by the latter to junior professionals and technicians working under his direction. The possibility that an exceptional nonprofessional employee may be able to make creative contributions, given time and opportunity, should not be overlooked.

Conclusion

Like any activity requiring skill, management must be learned by doing, but will be learned better if practice is accompanied by reflection, self-criticism, and vicarious learning from the experience of others shared in conversation or in reading. As an activity that works upon reality through other people, it is not complete in itself. The manager is dependent for his ultimate accomplishment upon the quality and effectiveness of his

staff and cannot expect to judge his own effectiveness in his day-to-day relationships with his staff with any claim to accuracy. The job calls for faith in oneself, faith in others, and a considerable element of spontaneity. Any brief analysis creates an impression of tidiness and deliberateness that is often foreign to the reality. If we grant these statements, the best hope for a discussion of functions is that a certain fraction of other managers, reading it, will find something in it that meshes with and reinforces or extends their own thinking in some respects.

THE RESEARCH MANAGEMENT STUDY GROUP PROGRAM OF THE INDUSTRIAL RESEARCH INSTITUTE

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In 1957, as President of the Industrial Research Institute, I appointed a special Quo Vadis Committee consisting of R. H. Lueck, Chairman, and R. W. Cairns, R. G. Chollar, D. P. Krotz, and H. S. Turner, all members of the Board of Directors, to consider and recommend future activities of the Institute.

At the 1957 Fall Meeting of the IRI Board the Committee recommended that the Institute establish a series of intimate conferences on various facets of research administration. The Committee felt that, with the growth and changes in industrial research in the past decade, much of the published information on the administration of such research was outmoded and that many recent papers in the field were redundant and trite rehashes of previously reported information.

The Committee knew that there existed within the IRI membership an up-to-date, diversified, and multilevel fund of information related to all the areas, phases, and processes of research administration. The need for a systematic method of collecting, reporting, and disseminating such information was considered self-evident, and a study group approach to the problem was recommended.

The Board of Directors approved this recommendation of the committee and asked the President of the Institute to "appoint a committee to study and report on the feasibility of establishing a series of intimate conferences on specific facets of research administration and to recommend a plan of activity."

Accordingly, a Research Management Study Group Committee of seven was constituted under the chairmanship of Dr. George L. Royer. This committee quickly developed tentative plans for implementing the broad principles outlined by the Quo Vadis Committee and with Board approval set up a pilot study group on "The First Line of Supervision in a Research Organization." This two-day pilot meeting was held in January 1958 at Princeton, New Jersey, with some 22 individuals participating. In issuing invitations to this meeting an attempt was made to include two types of individuals: those with specific knowledge of the subject and those who could contribute to and evaluate the methods and techniques of conducting and reporting such a meeting.

The group, under deliberately loose guidance, was able to establish quickly a sound method of handling the area under discussion and was able to distill out of its combined experience and knowledge an impressive number of principles on which there was general agreement and a smaller but important number of points on which there were strong diametrically opposed views. The points of disagreement, as might be expected, were generally considered by the Study Group members as the most interesting and constructive areas for discussion.

It was the unanimous opinion of those attending this pilot group meeting that the program was successful and could and should be expanded into a worthwhile activity of the Institute.

Following the success of this first pilot meeting two additional two-day experimental meetings were held in March 1958 on the same subject—one in New York and one in Chicago*. The

* A paper by James Hillier, *Research Management*, 1, 225 (1958), presents some of the details of organization of these study groups and reports the major conclusions reached. These first meetings also resulted in two papers on job classification procedures, one by I. Goldman, *Research Management*, 2, 45 (1959), the other by F. D. Leamer, *Research Management*, 2, 53 (1959).

three meetings taken as a whole made it abundantly clear that worthwhile information could be readily developed by the study groups. At the same time the meetings demonstrated the difficulty of writing clear statements or summaries of the discussions which could be useful in disseminating the group findings to all interested in research administration. It was obvious that volunteer part-time reporting was not wholly adequate, and that concentration on this phase of the operation was needed. There was now, however, no doubt of the need for and the value of the study group program.

Accordingly, the Committee set up a series of six two-day study groups for 1959 on three topics: the original topic of "First Line Supervision," plus "Environment for Creativity" and "Job Status as an Award for Scientific and Administrative Accomplishments." All of the groups met in New York City at the offices of the Industrial Research Institute, which were enlarged to accommodate this program.

In an attempt to overcome the reporting difficulties A. E. Staley Manufacturing Company offered the services of their Director of Chemical Research, Dr. James A. Bralley, who took a leave of absence to coordinate and report the entire 1959 study group program. This procedure proved much more workable than the previous arrangement.

The success of having one man responsible for the coordination and reporting of a series of meetings led the Institute to increase its staff in order to handle the Study Group function. Mr. Louis Marshall joined the Institute staff in the fall of 1959 as Conference Assistant and Secretary of the Board of Editors of Research Management. He coordinated the 1960 series of two-day study groups which again were six in number and covered three topics: "Increasing the Technical Competence of Research Workers," "Optimizing the Relationship Between Research and Marketing," and "Selection and Placement of Research Personnel." The meetings were held in February and March, four at the Institute offices in New York and one each in Chicago and St. Louis. Re-

ports on these meetings are in progress and will appear in future issues of Research Management.

Participation in the Research Management Study Group Program has thus far been limited to personnel of IRI member companies. Each participant was selected by the Study Group Committee on the basis of the contribution he could make. Group size has been limited to a maximum of twenty.

Without question, the study group program as developed by the Industrial Research Institute is an excellent means of distilling the modern practices of research management into useful reports suitable for dissemination. The study groups have not been formal teaching workshops, but all participants have learned a great deal in the course of the discussions. The end products of the study groups do, however, afford an excellent basis for group discussion designed to instruct.

The first proceedings of the IRI Study Group program, Dr. Bralley's report on the Environment for Creativity, immediately follows in this issue. Other proceedings will appear in subsequent issues. Reader comment and criticism will be appreciated.

PROCEEDINGS OF INDUSTRIAL RESEARCH INSTITUTE STUDY GROUP MEETINGS. NUMBER 1. THE ENVIRONMENT FOR CREATIVITY*

Reported by
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Introduction

Agenda

The agenda for the two-day meetings was divided into three parts:

(1) Discussion and definition of terms with the intent to establish sufficient agreement on language to avoid confusion in subsequent discussions.
(2) Brief examples of deliberate actions aimed at the establishment of more creative environments.
(3) A working session devoted to the discussion of psychological, organizational, and fiscal factors which appear to influence a creative environment.

* This paper is based on two Industrial Research Institute Study Group Meetings, held at the Institute's offices in New York on February 19–20, 1959,

After dinner, the first study group heard a discussion by a psychologist on the subject of creativity. The second study group heard a similar discussion by a well-known graphologist.

The last item on the program for both meetings was a discussion of recommendations to the Industrial Research Institute for further study group subjects.

Discussion and Definition of Terms

Purpose of the Discussion Group

It was agreed by all present that one broad generalization can be made. Namely, it is the purpose of all industrial research organizations eventually to make money for their company. Furthermore, we all have one basic raw material to work with—people. The purpose of this discussion group was to explore ways and means of deliberately optimizing the research environment to encourage the maximum creativity from the research organization. It was recognized that we cannot disassociate the *environment* for creativity from the *personal attributes* an individual must have to be creative and successful in going through the creative process. The discussion of these personal attributes proved to be an important part of the study group's deliberations.

Scope of the Present Discussions

It immediately became necessary to clarify whether the group wanted to discuss creativity over the whole range of human en-

and March 19–20, 1959, on the subject of "The Environment of Creativity." Dr. W. M. Bright, Director of Research, Lever Brothers Company, and Dr. James Hillier, Vice President for Research, Radio Corporation of America, were discussion leaders and cochairmen of both of these two-day meetings. The 31 participants in the meetings were from the upper echelons of research management of 31 company members of the Institute.

This report is intended to convey the sense of the Study Group Meetings, but is not to be construed as a statement of policy by the Industrial Research Institute nor an endorsement of the views expressed.

deavor or to restrict itself to the scientific research area. This was considered important because the environment in which people work best will probably differ with the area of effort. The groups agreed to confine their discussions to the narrower segment of research in order to make the discussion more pertinent to our problems. The group was not interested, for the present, in discussing creativity in such fields as the arts or advertising.

It was agreed that creativity is something that can be applied to any phase of research or development, and even to management; that it is not, for instance, restricted to research qualifying for a Nobel prize. Some of the participants felt the groups should study environment over the whole range of the organization's activities, from top management to research and other corporate functions, and see how this environment changes from one location to another where the functions are different. However, it was finally agreed the participants would limit their discussions to professional workers at all levels, excluding the laboratory services work such as routine analytical operations.

Next considered was the magnitude of an individual effort that should be deemed truly creative. The group expressed interest in all things considered creative by the companies represented. This included the whole spectrum of creative work from broad, general, fundamental discoveries, to the very small, selective ideas that may apply to only one of hundreds of products. In short, the groups were interested in talking about the environment for creative acts that are of interest to industry; they did not wish to encroach upon artistic fields. Therefore, all discussion from this time was confined to creative environments for the professional research or engineering worker.

Definitions of Creativity

Most of the conferees had their own definitions of creativity which could, almost without exception, be combined into one or more of the following:

(1) Creativity is the attribute of forming new concepts or the bringing about of new, imaginative relationships.

(2) Creativity is the act of going out to discover a certain fact and not the actual discovery of the fact itself. For example, the finding of a new world was not creative, but the idea of going out and looking for it, and having the concept that it must exist was creative.

(3) The essence of the creative process is the putting together of a number of seemingly unrelated facts or principles in such a way as to have a new end result.

(4) Creativity is the production of some useful thing that has not existed before.

(5) Creativity is the organization of thoughts or empirical data to yield a new useful concept, process, or product.

Semantics of Terms Used

The groups felt it was important to differentiate between productivity, which is simply a matter of turning the wheel to grind out data, and creativity, which is the sporadic—almost probability relationship—type of results. It was the latter activity in which the discussion groups were interested.

This led to the necessity for distinguishing between the terms creativity, discovery, and invention. The results of a recent meeting* on this subject were of help here. The definitions arrived at by that group and accepted as valid by the present study group members were as follows:

> We *create* when something is caused to come into existence or when something is produced as a new construction out of existing materials.
>
> We *discover* what has existed previously but has not been known to us.
>
> We *invent* combinations or arrangements not before in use.

* University of Chicago Seminar on Creativity and Industrial Research Administration, January 21–23, 1959.

Importance of Environment

Undoubtedly there is more than one ideal environment for creative work, depending upon the background of the individuals and their own personalities. Some people work better in one environment and others work better in an entirely different one. This is borne out by the fact that people in authoritarian countries, such as Germany and Russia, working under a presumably more restrictive atmosphere, are equally as creative as those who work in a free or permissive atmosphere.

Some even questioned if it is really necessary to have a *good* creative environment. Many inventors create their own more-or-less favorable environment, but others break down under the strain of adversity. The truly creative person accepts and rejects, as an individual, the things he wants and does not want in his environment and, in a sense, does create a favorable atmosphere for his work. This is especially true of the outstanding geniuses in science. Although few and far between in history, they often created their own favorable environments and produced regardless of their surroundings.

The groups agreed they could talk only in generalities which may apply to the average situation, but must be modified to fit specific cases. Also, it was acknowledged that, although we can do a lot to alter the environment of our scientific workers, we may not be able to do anything about changing their innate talent.

Deliberate Actions Aimed at the Establishment of More Creative Environments

Brief case histories of the effect of environment on creativity were presented by several attendees at the study groups.

Example No. 1: Rejuvenating a Gadgeteering Group

A Company which had some 12 to 17 people, out of a total of 500 in the Research Department, working on the development of

new mechanical devices needed by any person or group in the company had been obtaining only two or three sucessful products per year from the effort. Management undertook a new approach to stimulating the men in this gadgeteering group. First, they told the men they should work only on nonpurchasable things, i.e., gadgets that could not be bought in the market. Second, they should not worry about the problems of producing these items themselves; they need make only a prototype and the company would then arrange for production or manufacture by an outside agency. Third, they promised the men that, if the items were not subject to commercial exploitation, they could publish their work.

After a six-year trial period, it is obvious the program has been very successful. Some fifty disclosures per year, on the average, were obtained from the group during this period. Thirty to forty devices invented by these people are now in actual production. The increase in fruitful ideas of the group has been about tenfold.

Although this program of stimulation was not instituted for monetary reasons, attendant publicity for the individuals in the company has been very beneficial to all concerned. The men involved in the program were chemists, chemical engineers, physicists, and electronics specialists. They were scattered throughout the organization, the largest single group consisting of three or four men.

All individuals working in the program had a high degree of autonomy and were allowed to do pretty much as they pleased. For instance, the pilot-plant man was assigned the responsibility of providing any instrumentation or mechanical aid necessary to do the work of the pilot plant better or more efficiently by any means at his command. He was so successful that an additional man had to be assigned full time to exploit the results of his efforts. One small device for regulating vapor pressure in a refining operation was responsible for saving the company some $100,000 annually in raw materials cost alone.

Example No. 2: Organizing a Pioneering Group

A number of years ago, a large manufacturing firm organized a Special Services group consisting of some 50 technical people, a comparatively small unit in their research division. The group as a whole was assembled very slowly, and management had a chance to be very selective in their choice of the personnel making up this group. Consequently, it has high morale and functions as a closely knit, smoothly operating organization. The director of this group told how he has divided it into four operating units and how, in a staff position, two senior scientists were completely on their own. A small staff of administrative people complete the group. The group assignment is to originate problems which can be handled by the development and production departments of the company.

The director outlined five devices he uses systematically to stimulate the creativity of his organization. One of these is to have conferences with all his people once a month. He talks for some thirty minutes at this time and tells them all he knows about the company's current business plans. Secondly, they prepare together and issue an *annual planning report* for both short-range and long-range goals of the company. Third, the Steering Committee, consisting of the four section leaders, the two senior scientists, administrative director, and the research director, have a *monthly dinner meeting* at which they discuss the selection and assignment of new personnel and problems. There are some twenty-six active projects for the fifty people involved in the Special Services section. A fourth device the director uses is to have *constant communication* both upward and downward in the company by frequent meetings, reports, and verbal exchange of information. The fifth device used is a *weekly seminar;* eventually, everyone has a chance to present a formal paper at this meeting.

Anyone in or out of the group can present a new idea to the Special Services group. Often the man has a hard time defending his idea, but the discussion is provocative and fruitful. Fifty or more people from the research division may attend these meetings,

and the programs are well prepared;professionally made slides are used, and there is a definite time limit on the talk. Occasionally, popular subjects have to be presented twice to accommodate all the people who want to hear the discussion.

Members of the Special Services group spend about 50% of their working week on their own assigned problems; another 10% is spent in administrative work; 30% of their time is spent in consultation with other groups within the company; the remaining 10% of their time is spent in strictly blue-sky work. The director felt that this organization and approach has been quite successful in his company and the mere fact that top management has done nothing to change the set-up is considered proof that they are happy with the way it has functioned in the fundamental research area over a long period of years.

Example No. 3: Projecting Research Needs

At the other end of the research spectrum, namely, product research, a research director pointed out that his greatest problem has been to get his people who conduct product development research for the operating departments, sales, and others to look ahead and predict what their future research needs should be. He has, therefore, instituted a program for getting these research people to come in and predict the outlook in their respective fields five to ten years ahead and to say what type research should be done to help them in the future. He feels that market surveys and projections tend to convince people that life is going to go on in the same old way indefinitely, and this has a very inhibiting influence on research programs. The attempt to project needs as much as five years ahead is hard, disturbing, and challenging work. It has made it apparent that a good deal of current research is outmoded and should be eliminated entirely in favor of working on more advanced and revolutionary ideas. This new program was instituted just one year ago, but today they have already come out with new problems and worries which have not been recognized here-

tofore. It has stirred things up tremendously and presented some reverberating challenges to the research organization.

Example No. 4: A Technical Challenge

One research director said that in looking around to see what his group should be doing in long-range research for data processing, he found they had a few ideas, but he was not very happy about the whole situation. The Government, however, asked if he would help them develop a millimicro-second computer. He considered this a terrific problem for his research people and accepted the challenge, despite the strong opposition of some of his research staff. However, one year after they took on the assignment the researchers could say, "This is easy—we can do it to a tenth of a millimicrosecond." New ideas came out in ways they would never have predicted, and this has resulted in a lot of creative activity. They are off and running with this development, and many new developments are coming about as a consequence.

Example No. 5: Exploratory Research in an Oil Company

Some six years ago, upper management in a large oil company was disturbed by the fact that new concepts were not being evolved for fuel processing. Therefore, they deliberately set aside 10% of their research crew and budget to try to increase this type of work. They tried specifically to create a good atmosphere for the 10% of their staff assigned to this group. They have learned there is nothing particularly mystical about the creative act. It consists of two parts; first, the origin of the problem and, second, the provision of the tools to solve the problem. Most important, the individual who works on it must have the desire to solve problems, and he must have the ability to relate currently available knowledge to his own problem. The most difficult facet of this work, administratively, is to find the problem-centered individuals suitable for this group.

The most useful knowledge in this area is that based on fundamental concepts rather than on factual knowledge of operations; i.e., carbonium-ion theory is more important than familiarity with operational details of a process. The environment a man works in must be saturated with problems. It must be a loosely scheduled environment with freedom to operate and freedom to deviate from standard practices. They pick individuals who are specialists in their areas.

The exploratory effort is separated, but not isolated, from the rest of the research division. Not all the divisions participating in this effort felt they had to separate exploratory research from the remaining organization. The company divided its effort into three areas: chemical research, physics, and engineering. They used a fundamental attack to gain broad knowledge of chemical fields involved rather than specific reactions. They encouraged a professional atmosphere, and the likelihood of a man digressing into a sideline of research is quite high.

The original decision had been to permit 10% of the research effort to go into this exploratory area, but the experiment was so successful management felt they could devote 25 to 30% of their effort to this exploratory work. The group has been responsible for some 70% of the patents coming out of the organization. An improved reforming process, several new reactions, and a technique for restoring activity and selectivity to a used catalyst are examples of specific accomplishments. In the past year, the group has written articles and given four talks; this indicates the high degree of professional attainment of their exploratory group.

Of the original personnel assigned to this group, only three are still in it. The others asked to be transferred, principally because it was found they were not of the problem-solving type; this illustrates how management's biggest problem is to find the problem-centered individuals suitable for this type work.

It was stressed that the principal difference in environment given this group is the degree of freedom of their operation in contrast to the rest of the research organization. Organizationally,

it is similar to the other groups. Supervisors may have three people working under them, and they report to a section head. The supervisor is a highly competent technical man who functions as a sounding board for ideas of the men under him. He is an outstanding scientist in his own right.

Initially, the problems chosen were handed down from upper management because of the obvious need for work in certain broad areas. Now, more of the problems are coming from lower echelons, from the men who are creating their own research subjects. The breaking up of the problems into smaller specific areas is done by the research men themselves, as a logical consequence of their professional qualifications to work on certain aspects of a problem.

Several management mechanisms are used to insure the saturation of the group with problems. Regular weekly meetings are held for discussions of new problems conceived or arising out of the work. Many of the people in the group work weekend days because of their intense interest in the problems. The men are provided with the best laboratory assistants available and are allowed to bring them in at any time of night, or even on weekends when they are needed. Most of the men are under 35 with only two to five years' experience in this area. Management feels it is good to put men in this group directly from the university campus.

The research director pointed out they couldn't use this type organization for the rest of the research groups in his division because it is necessary to avoid gross deviation from the main line of work in the orthodox development groups. They cannot afford to have a specific problem go unsolved while a man runs down an interesting by-path.

Example No. 6: Diversification by Management Edict

The research director of a large manufacturing company began by saying that creativity is something that occurs only during very short time intervals and quite rarely. Yet, in the summation, these ideas are far reaching and a man has to be judged on his pro-

ductiveness during these brief moments. He feels the creative act can be likened to the energy released from an explosion; after the initial event, we are running downhill on the energy curve at a very high rate.

An upper management decision was made several years ago that their company should attempt to diversify by research; about 15% of the total research effort was diverted to this assignment. Now some 85% of their sales volume is geared to the new products and processes created by the diversification group. What has been accomplished is due to a combination of three principles: (*1*) to encourage people to do things, (*2*) to attempt all the way up and down the line to encourage new things, and (*3*) to leave the research men alone.

Example No. 7: Is Management Creative?

Another participant said they have not been able to measure any really significant increase in creative contributions at his company due to the 10% exploratory time available to the men. Their so-called "open project time" is usually devoted to solving their current problems more effectively. He does feel that the installation of a computer which permits the statistical design of experiments has been of help in increasing the output of the laboratory.

The establishment of a scientific management committee is apparently helping to stimulate newer ideas for future research work. He feels that encouraging creativity of research management is fully as important as increasing the creative output of individual research workers.

As a result of thinking generated in the scientific committee, several home discussion groups sprang up spontaneously. There was no management edict requesting this, but these groups have been rather productive and stimulating to date. They cross discipline lines; physicists and physical chemists frequently get together with organic chemists for these home discussions. When the men are made aware of the company competitive situations and eco-

nomic factors making solution of a problem very desirable, this is a powerful spur to their creative instincts. When they thoroughly understand and are sympathetic with company problems, they identify themselves with the problems and try strenuously to solve them. This research director feels that the creation of a sense of urgency is not a deterrent to creative action on the part of individual workers but rather a spur to their productivity. Another valuable spur is the discussion arising from presentations made by visiting academic consultants during the course of regular seminars. These seminar discussions are then often carried over into the discussion groups meeting in individual homes.

Example No. 8: Top Management Changes Goals

Another research director present gave a short history of research in his company during the past ten years. In 1948 they had only four products, and top management sentiment was that this was all the company needed. However, this philosophy was upset when the president retired and a new management took over. The new regime established the philosophy and policy of having research develop its own products. A central research department was created by moving all outlying laboratories into one location. Although the people involved resented this highly, and problems were *assigned* to them for solution, the effort has been highly successful; and the company now has a well-diversified and strong product line. This is a case of creative research management instituted from above. For this reason, the research director does not feel that a laissez faire policy is necessary for successful research accomplishment. In 1958, 60% of their sales were from products they did not have in 1952. He acknowledges that when broad fundamental research knowledge is a goal, you cannot build the same kind of fire under the research department as in the case of a product-oriented company, such as his. One of their greatest technical breakthroughs was made by assigning a fundamental research man, who was a relatively poor administrator, to the job of directing

product development people to solve a particular problem. He was completely successful in stimulating his people to come up with a solution.

One comment was that this organization has still not reached the point the oil company described in Example No. 5 reached several years ago when management decided to stimulate ideas from the research workers themselves.

Psychological Traits of the Individual

In a paper presented at the IRI Meeting in Washington, D.C., October 20, 1958, Dr. Hillier, one of the present discussion leaders, reviewed the characteristics of a creative individual. The study groups were now asked to consider these and to elaborate on the points mentioned. Of the five psychological characteristics of an individual that are most important to his being creative, the first and most obvious one is that he must have a high level of native intelligence. The group also felt that creative people should have broad interests rather than very narrow ones, although it was acknowleged the same invention could be made by different people using different approaches, that is, someone with a broad outlook could arrive at the same end point as another person in a narrowly concentrated field. The group felt we are still not sure that thought processes are any different in creating new things in a broad fundamental research area than at the other end of the spectrum in narrow specific areas—the nuts-and-bolts type research followed in product development.

The second characteristic is that man the creative must be completely dedicated to and absorbed in his field. He must have the natural curiosity of all human beings to a very high degree. However, it is not necessary to direct a man's efforts along a particular line as long as he is working in the desired discipline. The group agreed it is better to choose a man, say, in solid-state physics or electronics, and to put him to work to discover whatever he may be able to learn in his own field than to restrict him to a small specialty line in that field.

Third, a man must be versatile, adaptable, flexible, and capable of deep interest in any problem he studies. He should have available all information on the subject engaging his attention.

Fourth, he must have a temperament which always keeps him dissatisfied with the *status quo*. Several men said they look for uncommon patterns of thought in people they interview in order to pick out the creative ones. Divergent thinking seems to be one of the most important characteristics of the creative individual.

Fifth, he must be so thoroughly familiar with his specialty that any departure from the normal pattern alerts him to explain the cause of this divergence. He should be sensitive not only to slight departures from the norm but eager to correlate all new facts with his previous knowledge of the subject. Although it was agreed that most creative men are optimistic and enthusiastic workers, it was also pointed out that they are usually introverts. One manifestation of their optimism is that a creative worker is not discouraged by a negative result. He looks upon this as an opportunity to explain something that will shed more light on his particular problem. In the process, frequently something new is discovered.

Environment Factors Aiding Creativity

In proceeding to a discussion of environmental factors affecting creativity, the study group leaders emphasized they would like to consider the first half dozen or so factors as being, really, policies of management which aid creativity. The first of these is freedom of action. All the research organizations represented professed to have this as a keystone of their policies. They try to afford their people as much freedom of action as possible, provide them with the tools for research, and avoid attempting to direct a man's work. This is accomplished by having the supervisors make a point of getting the men themselves to say *what* they want to do, then urging them to do it. All concerned agreed the bench worker should have the principal say on *how* to do it. The project system used by most organizations is based on the initiation of projects

by any research worker who has an idea. This mode of operation is more feasible for companies indulging in fundamental or basic research than it is in consumer product-oriented research organizations where upper management frequently plays a very important part in the origination of research ideas.

Most of the representatives present said that their groups allot 10–15% of their time to open projects. This is for purely exploratory work, about which they have to say nothing to their superiors or anyone else until they have proved the worth of an idea.

Several people said they try to keep rules and regulations at a minimum and avoid the military-type organization and the use of terms such as "management" and "top management."

Another means for promoting freedom of action is to have the individual bench worker meet with his superiors and co-workers periodically to discuss the present status of his project, current research reports, and future courses of action to be taken.

The study groups noted several pitfalls to be avoided in trying to promote maximum freedom of action. One of these is that although, on paper, all professional people are allowed to spend at least 10% of their time on any problem their interests dictate, in actuality, they often spend less than 1% of their laboratory time on projects of this sort. This is because they become so interested in successfully solving their formal assignments that they just never get around to doing any work on their own. It may be that the desired result could be attained by giving a man a certain number of months free time every few years (say, six months in five years), to work on nothing but his own ideas, rather than two days per month as a regular diet.

Sometimes a fire-fighting job comes along that has a very high priority for solution. When this happens, research management must resist the temptation to assign the job to the exploratory group.

A further hindrance to freedom of action, of a more subtle sort is the attempt to discourage a research man from taking a project he has originated all the way into the actual development

and plant design stages. Most research men are just not cut out for this type of work, and it is really a waste of their creative talents to allow them to do this, although they may wish to do so. Sometimes, however, a man has to be permitted to carry through a development in order to prove to him, once and for all, that this is a bad mistake in his case. It is sometimes extremely difficult to pull a man off a project of this sort, because he has a better sense of security in the familiar working area and is reluctant to return to the bench and start looking for new discoveries.

It sometimes happens, in the case of companies who do not have an enlightened research management, that the lower research echelons have ideas that they are never able to put over to their hide-bound upper management. When this happens, the only alternative is for the research worker to maintain his individual professional status by either continuing to do exploratory work on his own time or by changing jobs to obtain a more permissive environment.

Well-Understood Objectives—A Vital Necessity

All the participants agreed that research objectives should be natural and real; phony deadlines for the completion of research projects should not be set up. One research director said that most of his time is spent in explaining to his people the objectives and urgency of the research program and in helping define goals for his men. This in itself creates a highly permissive atmosphere for research. He said that he has decided to run his organization as a "translucent black box" as far as management is concerned, that is, he wants management to know, in general, the nature and importance of the problems on which the group is working; however, he does not want management to get so involved in the details of the work that they will annoy the research workers by undue attentiveness. Others agreed that, as long as some good results are forthcoming from the program, management does not have to be inquisitive about the mechanism of the research. There-

fore, they try always to have a few easy problems and processes that will yield immediate, positive results they can discuss freely with nontechnical management, along with the more difficult problems in the program.

Several research directors stressed they are not satisfied with the way their managements set their company objectives before the research people. Management is interested principally in terms of growth, sales, net, profit, etc., rather than in translating these into terms of broad product goals. As a consequence, company objectives are restated for the research people by the research department itself, with practically no guidance from above.

Representatives of the electronics, chemical, and consumer products firms agreed their main problem is to define the research goal. Even their customers, whether the Federal Government or a small consumer, do not really know what they need or can use to great advantage until it is pointed out for them by an aggressive research organization.

One director said that he feels one of the most potent devices for stimulating creativity is to have product-division managers talk directly to the research directors and point out to them what they need in the way of future developments and, at the same time, show their appreciation for what has been done in the past. Generally, it has been found that market survey studies are practically worthless for guiding research; they can demonstrate that anything is practically useless to do. It was also emphasized that it takes about $10 on a development project to exploit $1 worth of research, and about $100 in production facilities to exploit the $1 research expenditure. Therefore, companies feel they must avoid research on many more things than they can afford to carry on into product development and production.

Broad basic programs and new fields are set principally by the technical man, who works up the statement of the problem, its justification, scope, requirements for equipment, manpower, etc., needed to carry out the research. The more practical the problem and the nearer the applications area it lies, the more technical direction it gets from the researcher's supervisors. Good com-

munications are essential in setting up realistic objectives and maintaining freedom of action in a research program.

Sources of Urgency

It is recognized that some degree of pressure is very desirable in stimulating creativity, but the pressures should be natural ones, recognized as being valid by the researcher. One of the best sources of urgency is to have a big backlog of intensely interesting projects awaiting some man's time. The people in the research program should feel there is never quite enough time, manpower, or money to do all they should like to do on any project. The setting and revision of deadlines is helpful but should not be overdone. Frequently, professional meetings are extremely useful in promoting the sense of urgency, and this is really a better source of pressure than continual harassment by the research supervisor.

All felt that no one person should work indefinitely on highly urgent and time-important programs. It is good to shift men who have been on crash programs and under pressure for some time to more relaxing problems, and choose other individuals for the next crash program.

High Level of Activity

This is one facet of the sources of urgency just discussed. Everyone acknowledged that creativity is encouraged if the general environment is one of a high level of activity. People are stimulated by seeing other people engaged in constructive work. It has been found very helpful to shift men from one work area to another because their productivity often tapers off after an initial flurry in the first six months or year on a new project. This avoids their becoming stale in the current work. The only way this can be carried out is to always have many more problems than can be adequately manned.

Horizons Unlimited

Several of the conferees were most impressed with two sentences from Dr. Hillier's paper referred to above, and suggested that these two sentences should be on the wall of every research man's laboratory as a working guide in attempting to be creative. The sentences were: "The creative man continually challenges the rules of nature. Man-made rules are even less acceptable without question."

Means for implementing the goal of having unlimited horizons merge into the area of stimulating associations. It is recognized that participation in meetings, the bringing in of professors and graduate students to work during the summer, broad reading programs to keep up with advances in other fields, as well as the maintenance of a challenging program and the constant upgrading of the research staff are all means to this end. Many felt that the use of 10–20% of their budget to support blue-sky ideas tended to encourage the best imaginative efforts in the research division.

Recognition and Rewards

This multifaceted subject was introduced with the proposal that the group first discuss the six principal incentives listed by Stein who reported that the bench workers themselves listed their most compelling reasons for increased creativity, in the order of their standing, as: (*1*) substantial salary increase, (*2*) promotion with increased responsibility for scientific personnel, (*3*) increased opportunity to select own problems, (*4*) additional laboratory technicians or other assistants, (*5*) opportunity to attend scientific meetings, and (*6*) flat cash bonus.

Salaries Must Reflect Accomplishment

Some people doubted that salaries had any real effect on creativity beyond a certain point, but all agreed they must be competi-

* Paper presented at Fall Meeting, Industrial Research Institute, Pittsburgh, Pa., October 21, 1957.

tive with other laboratories or the organization will lose its creative people. One person remarked that even if the creative man does not pay much attention to his salary, one can be certain that his wife usually does. All agreed that salaries of creative people are important to their continued productivity and high morale, and that they must reflect quite quickly the company's idea of the research man's worth when he makes a specific accomplishment. The question of salary administration and merit rating systems was not discussed at any length.

Promotion Must Reflect Accomplishment

It was pointed out that in the past the most creative people were those who attained administrative positions; this came about as a matter of necessity. However, many men do not want increased responsibility for the direction of other people's work as a reward for their creative accomplishments. The double ladder of administration and technical work is necessary, therefore, to take care of the two different types of individuals found in all research organizations: the able research man who is also sensitive to people and able to work with them, and the scientific expert who is less inclined to deal with people and does not want to bother with administrative paper work. Some felt that this double ladder is not really necessary if the scientific man is able to earn as much money as the administrator and also has some symbols of status and prestige available to him.

Ten of the fifteen companies represented at one meeting said they used job titles as a reward for accomplishment. They feel that a complete across-the-board title structure is of great value in establishing status for individual scientists and as a means of rewarding them for their accomplishment.

Other large and quite successful research organizations have no title structure whatsoever in the fundamental research groups. In one company, a group leadership assignment is rotated, more or less successfully, among all people in the group, although the

men often insist that one of the more able members of their group take the leadership role. However, all the men in the group resent attempts to give any of them specific titles.

Apparently, a research organization can be operated successfully by both means, and tradition plays an important part in the acceptance of the particular system in any one place. In organizations having no title structure, the men often sign outgoing correspondence with a description of the actual job they are doing, such as so-and-so in charge of research on such-and-such a subject. This also applies to publicity releases and publications in the trade journals or the house organs.

It was acknowledged that in some communities, of the university type, the simple title of "Fellow" or "Scientist" or "Research Chemist" is significant to the community as a whole; but in communities of the industrial type this has no meaning at all, and the scientist does not have the status he really deserves in this community.

In summary, most companies use job titles as a reward for accomplishment, but some have been able to operate successfully without having to have a complicated title structure in their organizations. This last tendency is apparently spreading with growth of the professional and administrative ladders concept.

Increased Opportunity to Select Own Problems

This is taken to mean the man has more freedom of action as a reward for his past creative efforts. All the conferees were in agreement that, as a man showed his ability, he should be given a wider range to exercise his talents.

Additional Laboratory Technicians or Other Assistants

There was no disagreement about giving acknowledged creative people all the technical assistance they could use to forward their efforts. Several cautioned, however, that this should not also

mean an increased administrative burden of paper work for the scientist.

Opportunity to Attend Scientific Meetings

This is a prime necessity if a man is to attain professional recognition. Also, it comes under the head of stimulating associations and is helpful in formulating a good research program. Most companies follow a rule of thumb whereby the higher a man rises, the more meetings he has the privilege to attend. Frequently, too, the reading of a paper at one of these meetings is reason enough to add another meeting to the list he can attend in any one year. In other words, taking full advantage of the publication policies of the company increases the opportunities of the individual to attend scientific meetings.

Flat Cash Bonuses

Many companies have flat bonus awards for special achievements or incentive payment plans for their research men. At one company, some 10% of the research staff, on the average, receive extra bonuses each year. These are given for specific project completions of special value to the company, and everyone working on the project receives an award. The laboratory directors and supervisors are not eligible for these awards, as they come under a separate incentive plan.

It is not agreed how important these awards may be in actually stimulating creativity, but they may be quite important in preserving a high morale in some research organizations.

Publications Policy

First and foremost among the miscellaneous means of recognition for accomplishment is a liberal company publication policy. All those represented said they encourage publication of research

results wherever possible without violating security restrictions. Electronics companies publish about 49 out of 50 papers submitted to their executives for clearance. The proportion may be lower in other fields of research and, in some cases, companies impose a moratorium on publishing research results until this can be done without fear of encroachment by competitors. It was agreed that denial of the right to publish would be a restrictive influence on creativity, even for those researchers who do not care to take the time and trouble to write up an article for publication.

The thought was expressed several times that it is a professional duty of people doing basic research to publish their results. This is a means of paying their dues to the scientific community. Also, it helps create a very good reputation for the man's laboratory and makes it much easier to recruit able scientists as they graduate from school. A further benefit of publication is that the act of writing up a piece of work forces a man to think more precisely and results in better research. It broadens his knowledge in his field, draws a lot of interest and criticism from his peers, and stimulates him to thoughts that he might never have had otherwise.

Patent Award Policies Among the Companies

Many of the conferees agreed that the issuance of patents is a sign of professional attainment by the research worker. It was emphasized, however, that the number of patents a man may have is not necessarily a good index of his creativity; rather, the quality of the particular patents is the outstanding criterion.

Most of the companies represented pay $50–100 to each inventor when a patent is applied for, and another $50–100 when the patent is issued. One company awards $100 per patent application for a single inventor and $150 for multiple inventors (which sum is divided equally among the inventors). Another company felt that awarding of a large sum of money for a patent has a deterrent effect on creation of more patents. This is because of the strife generated between individuals over the inventorship of a particular patent.

The real purpose behind payments is to get a greater number of disclosures from the research workers. It was felt this has not worked out in practice; the number of disclosures has not been increased by this policy. It has helped in prosecuting the applications and getting them in, but it has not increased the total number of applications.

It is necessary to let people know their ideas are appreciated in order to keep the flow of ideas coming in. Several companies have experienced times when their patent departments were involved heavily in other affairs and could not process all company applications. During this period, the flow of applications dropped off sharply, because the research workers felt their efforts were not appreciated and the company was not trying to patent their developments. As soon as the work load on the patent department decreased, the flow of patent applications from the scientists increased again.

Sabbatical Leaves

Several of the companies represented had a system of sabbatical leaves. In a typical program, four such leaves are granted each year to people chosen by a special committee from those in the company who apply. The leave consists of one academic year in a university of the man's choice. The company pays three-fourths of a man's salary, plus his tuition and transportation, and it stipulates that the man attend a university in Western Europe.

Another company supplements this policy by sending four members of the technical staff each year on a tour of laboratories in Europe. The group travels together, all expense paid, to laboratories active in the particular field in which they are interested.

Another incentive, available in a few companies who have branch laboratories abroad, is the exchange of research men between foreign laboratories and those in the United States. While abroad, the visiting researchers attend scientific meetings and send back reports to the United States on these affairs. This exchange period lasts for about six months.

Miscellaneous Means of Recognition

Also mentioned as being effective tools in recognizing creative effort were such things as annual honor awards to the man presenting the best paper for publication during the year, notes of praise or letters of commendation from the president of the company thanking the worker and acknowledging the value of his accomplishment to the company, and the opportunity to present in person to the board of directors or a meeting of top company officials the results of a particular research program.

(This report will be concluded in the Autumn Issue of *Research Management*)